*Asian Journal of Advances in Agricultural Research*

*17(2): 1-10, 2021; Article no.AJAAR.77083*
*ISSN: 2456-8864*

# Influence of Day-length Enhancement through Night-breaking by Artificial Lighting on Off-season Dragon Fruit Production

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/AJAAR/2021/v17i230190
Editor(s):
(1) Dr. Daniele De Wrachien, The State University of Milan, Italy.
Reviewers:
(1) Roman Ioana, University of Agricultural sciences and Veterinary Medicine, Romania.
(2) Dobrin Aurora, University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania.
(3) Francesco Milano, Italian National Research Council, Italy.
Complete Peer review History, details of the editor(s), Reviewers and additional Reviewers are available in this link:
https://www.sdiarticle5.com/review-history/77083

***Original Research Article***

***Received 09 September 2021***
***Accepted 18 November 2021***
***Published 22 November 2021***

## ABSTRACT

The effect of artificial lighting in order to enhance day length for off-season dragon fruit production was examined for the first time in Bangladesh. A two factorial experiment was conducted at dragon fruit orchard of Agricultural Research Station, Pahartali, Khulshi, Chattogram to find out the best lighting duration and bulb for off-season dragon fruit production. Two factors were bulb and lighting duration for this experiment. The performance 6 hours lighting duration was significantly superior than other treatments in case of bud/pillar (43.80), fruit/pillar (43.80), fruit length (9.31 cm), fruit breadth (8.5 cm), individual fruit weight (344.62 g), yield (16.58 t/ha). 100 W IB having light intensity 225.96 lux showed superior performance over other treatments in case of bud/ pillar (49.44), fruit/pillar (34.56), fruit length (9.54), fruit weight (336.99 g), TSS (9.28%), yield (18.13 t/ha). The treatment combination (100 W IB for 6 hrs lighting) produced the highest number of fruit/

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pillar (36.33), bud/pillar (54.00), fruit length (9.66 cm), fruit breadth (8.99 cm), yield/ pillar (12.41 kg) and yield (19.85 t/ha).In control dragon fruit was unable to produce flowering due to short day length. So artificial lighting of 6 hrs with 100 W IB from 18 pm to 24 am was superior method for off-season dragon fruit production.

*Keywords: Day length; incandescent bulb; lighting duration; light-emitting bulb; light intensity; off-season dragon fruit; relative humidity; temperature.*

## 1. INTRODUCTION

Dragon fruit (*Hylocereus spp*.), is a cactus fruit which is also called pitaya, belongs to family Cactaceae and most extensively disseminated in six continents [1] but native to Central America [2]. Alternating wet and dry seasons with more sunshine and rainfall of 600-1300 mm is the prerequisite for the production of dragon fruit [3]. It is progressively attaining interest all over the world due to its tolerance to dry environments, resistance to diseases, flesh suitability and increasing demand around the world [4–6]. The health conscious consumers prefer it due to the antioxidant properties known as “betalain” [7]. Now a days, it is known as “Healthy Food for the Table,” due to the presence of low calories and more minerals and fibres [8–10]. In natural conditions, it produces fruits in summer and fall as it is a long-day plant [2,11,12]. There were some research on off-season pitaya or dragon fruit production in certain tropical areas such as Taiwan [2,11,12], Vietnam and Thailand [13] have confirmed artificial lighting and/or growth stimulators regulate flowering in dragon fruit. Several researchers found that the effective treatment for off-season dragon fruit production was four-hour lighting 22:00 pm to 2:00 am with 75-100 W Tungsten filament [12–14].

In Bangladesh, the popularity of this fruit is increasing day by day. It produces fruit during April-October in Bangladesh as it requires long photoperiod for flowering. But it cannot produce fruit during November- March as the day length was remaining short during that time. During off season, the available dragon fruits in Bangladesh were imported from abroad. As a result, the price of dragon fruit was very high during off-season. For its high market value, huge demand we should look after the year round production. Though there were lots of researches on off season dragon fruit production in abroad, but there was no research on off-season dragon fruit production in Bangladesh. So there have an opportunity to enhance off- season Dragon fruit production by artificial lighting. So this experiment has been undertaken to observe the influence of different types of bulb on off-season dragon fruit production.

## 2. MATERIALS AND METHODS

### 2.1 Experimental Site

The experimentation was done in the fruits orchard of Agriculture Research Station (ARS), Pahartali, Khulshi, Chattogram. The experimental area locates between 22.18 N latitudes and 91.89E longitudes at an average altitude of 20 m above the ocean level. The experiment was conducted to Agro Ecological Zone-23 which is called Chittagong Coastal Plains [15]. The physiographic component of these zones is low hills and basins. The soils are mostly moderately fine in texture having pH of about 6.5. The carbon-based material ranges from 0.7% - 1.47% in top soil and 0.38% -0.76% in sub soil [16].

### 2.2 Plant Materials

The orchard of BARI Dragon fruit-1which has red flesh was used for this experiment. One concrete post of 1.5 m height was used to support four plants. The spacing between two concrete posts was 2.5 m × 2.5 m. Eight-year-old dragon fruit plants were used for this experiment.

### 2.3 Treatment Combinations and Experimental Design

There were two factors viz. light intensity and light duration. There were two types of bulb, namely light-emitting bulb (LED) and incandescent bulb (IB). By using this two types of light, six lighting intensity was created, namely $L_1$=35 W LED, $L_2$=30 W LED, $L_3$=24 W LED, $L_4$=20 W LED, $L_5$=100 W IB (Incandescent bulb), $L_6$ =no light (control) was used as a one factor. Three lighting duration namely, $D_1$= 6 hrs (18 pm -24 am), $D_2$= 8 hrs (18 pm-2 am) and $D_3$= 10 hrs (18 pm-4 am) was used as another factor. Hence, there were 18 treatment combinations viz. $D_1L_2$, $D_1L_3$, $D_1L_4$, $D_1L_5$, $D_1L_6$, $D_2L_1$, $D_2L_2$, $D_2L_3$,

$D_2L_4$, $D_2L_5$, $D_2L_6$, $D_3L_1$, $D_3L_2$, $D_3L_3$, $D_3L_4$, $D_3L_5$ and $D_3L_6$. The four lights from each lighting intensity treatment were positioned at the four corner of a pillar at canopy level. White cloth was used around each treatment for reducing the influence of one treatment to another (Fig.1). The experiment was conducted in Randomized Completely Block Design (RCBD) which replicated thrice. The duration of artificial lighting was about 74 days.

## 2.4 Recorded Data

Data were recorded on number of bud/pillar, fruits/pillar, fruit length (cm), fruit breadth (cm), fruit weight (g), skin weight (g), skin thickness (cm), TSS (%), yield/ pillar (kg). The pillar yield was converted into ton/hectare. Besides these, the following data were recorded-

### 2.4.1 Temperature and humidity

Temperature and humidity data were recorded every day at 10 am and 22 pm during the experiment time. The data was recorded with the help of temperature humidity digital hygrometer (HTC-2).

### 2.4.2 Light intensity

The light intensity was recorded at 10 pm at three days interval. The light intensity was recorded at three different levels from each treatment viz at canopy level, at middle height of pillar and at near ground level. The final light intensity was calculated by averaging the three levels data. Lux meter (LX-9626) was used to record the light intensity.

## 2.5 Statistical Analysis

R-statistics software was used to analyze the data for analysis of variance (ANOVA) [17]. Box plot analysis was accomplished by using the STAR (Statistical Tool for Agricultural Research) version: 2.0.1.

## 3. RESULTS AND DISCUSSION

## 3.1 Box Plot Analysis

At present time, whether the data are normally distributed or not can be easily assumed by box plot analysis. Box plot analysis represents that the data of this experiment are normally distributed (Fig. 2).

## 3.2 Daily Temperature and Humidity

The daily temperature varied from day to day at morning and night (Fig. 3). The highest daily temperature was recorded as $28.9^0$ c and $23.1^0$ c at 10 am and 22 pm respectively. In contrary, the lowest temperature was recorded as $18.1^0$ c and $13.7^0$ c at 10 am and 22 pm. Though the experiment was conducted during winter season that means in short day, the day temperature was higher than the night temperature. The daily temperature was increased as the time progressed. Usually, the temperature determines the time required from flowering stage to fruit maturity [18].

The average relative humidity (%) was varying from morning to night (Fig. 4). The relative humidity was more at night (22 pm) than the morning (10 am). The relative humidity ranges from 33% to 84% in the morning. On the other hand, at night the relative humidity ranges from 58% to 99%.

**Fig. 1. Arrangement of light around a pillar (left one) and effect of one treatment to other was minimized by white cloth (right one)**

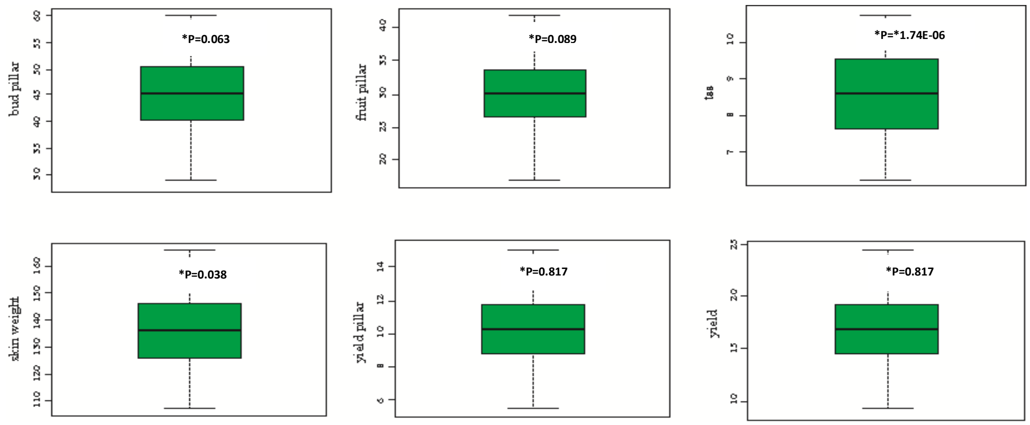


**Fig. 2. Box plot showing the distribution of data is normal**

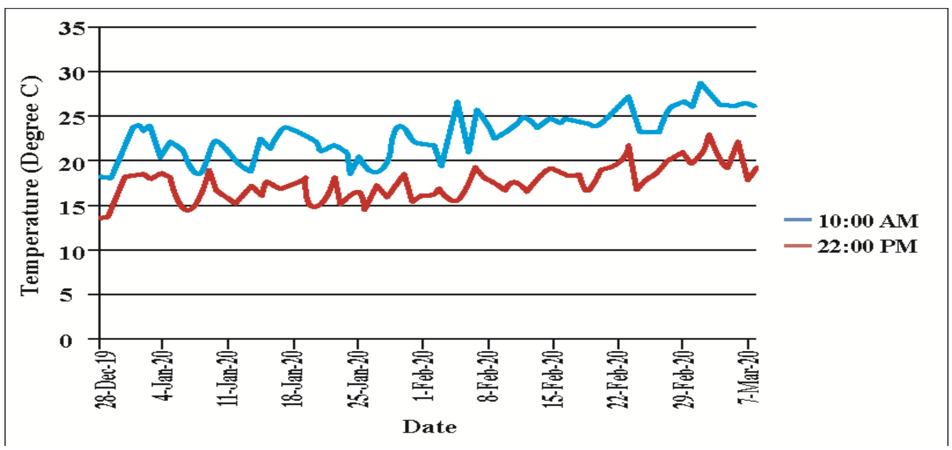


**Fig. 3. The daily temperature at 10 am and 22 pm during the experiment period**

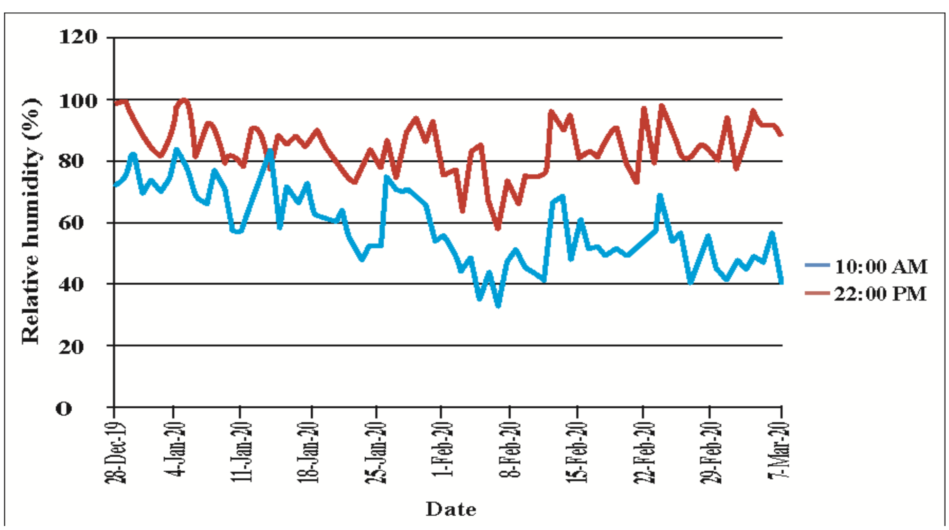


**Fig. 4. The daily relative humidity at 10 am and 22 pm during the experiment period**

### 3.3 Effect of Lighting Duration

Pitaya may be a long-day plant demanding an extended day length than a particular critical day length to stimulate flowering (2,6,11). Significant variation was found among the studied traits due to different type of light duration (Table 1). The performance of $D_1$ treatment was significantly superior then other treatments in case of bud/pillar (43.80), fruit/pillar (43.80), fruit length (9.31), fruit breadth (8.57), fruit weight (344.62), yield (16.58 t/ha) except TSS (8.84%) where treatment $D_2$ performed well. Some researchers found that more than 9 hrs of lighting after sunset could not induce flowering in sub-tropical like Israel [19]. Two hours night breaking by utilizing fluorescent bulb could stimulate flowering of pitaya grown in Chanthaburi, Thailand (13). Response of flowering to artificial lighting also depends on climate, species and color. Mostly the white flesh pitaya cultivar of Vietnam was unable to produce flower less than 4 hours night breaking by 100 W incandescent bulbs [20]. In Bangladesh, dragon fruit unable to produce flower during November to March due to short day length. Hence, during our experimental time, the induction flowering and fruiting is the confirmation that artificial lighting has positive effect on off season dragon fruit production. In our climatic condition 6 hours artificial lighting is found effective for offseason dragon fruit production. Thus, it was proven that nigh-breaking treatment by artificial lighting induced flowering during our experimental time. Considering yield and yield contributing characters, $D_1$ can be considered as a best lighting duration for off season dragon fruit production.

### 3.4 Effect of Bulbs

The average light intensity of different bulbs during experimental time was varying from each other (Fig. 5). The minimum light intensity (lux) was recorded from 100 W IB and the maximum light intensity (lux) was recorded from 35 W LED bulbs. The average light intensity (lux) was 792. 97, 534.62, 451.64, 424.97 and 225.96 recorded from 35 W LED, 30 W LED, 24 W LED, 20 W LED and 100 W IB respectively.

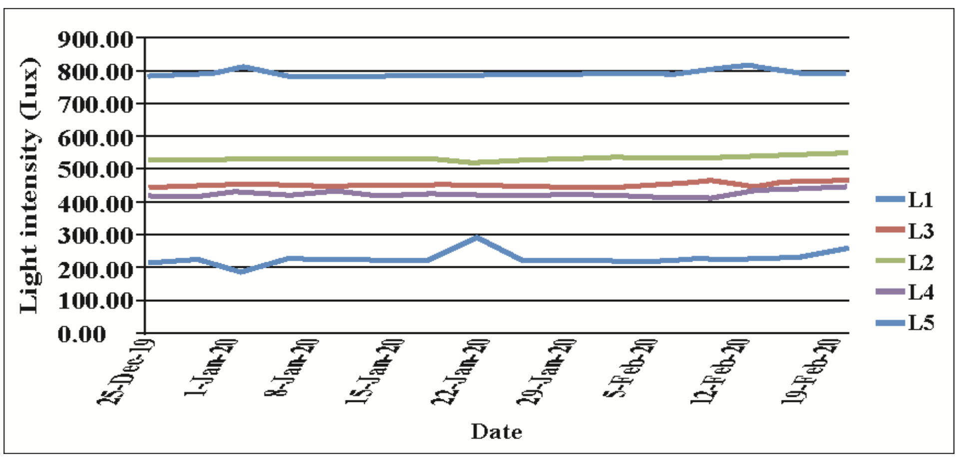


**Fig. 5. The average light intensity of different bulbs during experimental time**

**Table 1. Effect of lighting duration on yield and yield contributing characters of dragon fruit**

| Lighting duration | Bud/pillar | Fruit/pillar | Fruit length (cm) | Fruit breadth (cm) | Fruit wt. (g) |
|---|---|---|---|---|---|
| $D_1$ | 43.80 | 30.13 | 9.31 a | 8.57 a | 344.62 a |
| $D_2$ | 41.73 | 29.33 | 9.40 a | 8.35 b | 325.60 b |
| $D_3$ | 41.60 | 29.33 | 9.08 b | 8.22 b | 304.59 c |
| CV(%) | 11.61 | 12.71 | 2.55 | 3.48 | 7.07 |
| P value | 0.402 | 0.799 | 0.003 | 0.009 | 0.0002 |
| Level of significance | NS | NS | * | * | * |

*$D_1$= 6 hrs, $D_2$= 8 hrs, $D_3$= 10 hrs, NS= Non significant, *= 5 % level of significant*

**Table 1. Continued**

| Lighting duration | Skin wt. (g) | Skin thickness (cm) | TSS (%) | Yield/ pillar (kg) | Yield/ha (ton) |
|---|---|---|---|---|---|
| $D_1$ | 133.02 | 0.28 a | 8.21 b | 10.36 a | 16.58 a |
| $D_2$ | 139.98 | 0.25 b | 8.84 a | 9.24 b | 14.79 b |
| $D_3$ | 135.77 | 0.27 a | 8.20 b | 8.92 b | 14.28 b |
| CV(%) | 9.23 | 6.99 | 6.68 | 15.53 | 15.53 |
| P value | 0.326 | 0.001 | 0.005 | 0.031 | 0.031 |
| Level of significance | NS | * | * | * | * |

*$D_1$= 6 hrs, $D_2$= 8 hrs, $D_3$= 10 hrs, NS= Non significant, *= 5 % level of significant*

Day length enhancement may promote vegetative and reproductive growth of cactus plant [21,22]. Significant variation was found among the studied traits due to different light intensity (Table 2). Generally, more flowering was occurred by far-red light than other light [23]. Similar results were found in our experiment. Treatment $L_5$ having light intensity of 225.96 lux showed superior performance over other treatments incase of bud/ pillar (49.44), fruit/pillar (34.56), fruit length (9.54), fruit weight (336.99 g), TSS (9.28%), yield (18.13 t/ha). A 60 W incandescent bulb produced 25.4 fruits/ pillar [23]. In this experiment a 100 W IB produced 34.56 fruits/ pillar. Usually dragon fruit takes more time for budding under compact fluorescent lamp (CFL) bulb which had also worse flowering efficiency [24].Treatment $L_4$ with light intensity of 424.97 lux produced the maximum fruit breadth (8.58) and the maximum skin thickness (0.28 cm). Treatment $L_3$ provided the maximum skin weight (147.33 g) followed by $L_5$ (137.46 g). The critical day length for stimulating flowering of dragon fruit is about ≈ 12 h [11]. Dragon fruit usually cannot produce flower when the critical day length is less than 12 h [23]. Photoperiodism is considered as one of the major factors which promote flowering of plants [25–27]. These findings also supported our experiment findings. In control, there was no flowering and fruiting because the day length was not optimum for flowering. Hence, it can be easily understand that lighting has significant effect on off season dragon fruit production. Considering all aspect it can be said that treatment $L_5$ is best suitable for off season dragon fruit production.

**Table 2. Effect of bulb on yield and yield contributing characters of dragon fruit**

| Bulb type | Bud/pillar | Fruit/pillar | Fruit length (cm) | Fruit breadth (cm) | Fruit wt. (g) |
|---|---|---|---|---|---|
| $L_1$ | 44.11 b | 30.67 b | 9.25 b | 8.08 c | 305.23 b |
| $L_2$ | 41.89 b | 30.00 b | 9.23 b | 8.41 ab | 344.41 a |
| $L_3$ | 40.56 bc | 28.33 b | 9.11 b | 8.28 bc | 330.40 a |
| $L_4$ | 35.89 c | 24.44 c | 9.19 b | 8.58 a | 307.64 b |
| $L_5$ | 49.44 a | 34.56 a | 9.54 a | 8.54 ab | 336.99 a |
| $L_6$ | 0.01 d | 0.01 d | 0.01 d | 0.01 d | 0.01 c |
| CV(%) | 11.61 | 12.71 | 2.55 | 3.48 | 7.07 |
| P value | 7.28E-05 | 0.0001 | 0.007 | 0.008 | 0.002 |
| Level of significance | * | * | * | * | * |

*$L_1$=35 W LED, $L_2$=30 W LED, $L_3$=24 W LED, $L_4$=20 W LED, $L_5$=100 W IB (Incandescent bulb), $L_6$ =no light (control), *= 5 % level of significant*

**Table 2. Continued**

| Bulb type | Skin wt. (g) | Skin thickness (cm) | TSS (%) | Yield/ pillar (kg) | Yield/ha (ton) |
|---|---|---|---|---|---|
| $L_1$ | 131.29 b | 0.25 b | 7.70 b | 9.18 b | 14.69 b |
| $L_2$ | 130.24 b | 0.28 a | 8.01 b | 10.18 ab | 16.29 ab |
| $L_3$ | 147.33 a | 0.27 ab | 8.93 a | 9.36 b | 14.98 b |
| $L_4$ | 134.95 b | 0.28 a | 8.16 b | 7.50 c | 12.00 c |
| $L_5$ | 137.46 ab | 0.26 ab | 9.28 a | 11.33 a | 18.13 a |
| $L_6$ | 0.01 c | 0.01 c | 0.01 c | 0.01 d | 0.01 d |
| CV(%) | 9.23 | 6.99 | 6.68 | 15.53 | 15.53 |
| P value | 0.053 | 0.039 | 5.76E-06 | 0.0002 | 0.0002 |
| Level of significance | * | * | * | * | * |

*$L_1$=35 W LED, $L_2$=30 W LED, $L_3$=24 W LED, $L_4$=20 W LED, $L_5$=100 W IB (Incandescent bulb), $L_6$ =no light (control), *= 5 % level of significant*

**Table 3. Interaction effect between light intensity and light duration on yield and yield contributing characters of dragon fruit**

| Treatments | Bud/pillar | Fruit/pillar | Fruit length (cm) | Fruit breadth(cm) | Fruit wt. (g) |
|---|---|---|---|---|---|
| $D_1L_1$ | 40.00 d-g | 27.00 c-e | 9.52 a | 8.52 a-d | 370.70 a |
| $D_1L_2$ | 47.33 a-d | 33.00 a-c | 9.35 a-c | 8.58 a-d | 366.24 a |
| $D_1L_3$ | 43.33 b-f | 30.33 a-d | 8.99 cd | 8.23 c-e | 336.64 a-d |
| $D_1L_4$ | 34.33 g | 24.00 e | 9.05 b-d | 8.52 a-d | 309.75 c-e |
| $D_1L_5$ | 54.00 a | 36.33 a | 9.66 a | 8.99 a | 339.75 a-c |
| $D_1L_6$ | 0.01 h | 0.01 f | 0.01 e | 0.01 f | 0.01 f |
| $D_2L_1$ | 50.00 ab | 36.00 a | 9.42 ab | 7.79 e | 272.65 e |
| $D_2L_2$ | 39.33 d-g | 28.00 c-e | 9.27 a-c | 8.52 a-d | 352.56 ab |
| $D_2L_3$ | 38.00 e-g | 26.33 de | 9.30 a-c | 7.98 e | 338.90 a-c |
| $D_2L_4$ | 35.33 fg | 23.33 e | 9.53 a | 8.94 ab | 314.33 b-d |
| $D_2L_5$ | 46.00 a-e | 33.00 a-c | 9.47 a | 8.50 b-d | 349.53 ab |
| $D_2L_6$ | 0.01 h | 0.01 f | 0.01 e | 0.01 f | 0.01 f |
| $D_3L_1$ | 42.33 b-g | 29.00 b-e | 8.82 d | 7.93 e | 272.33 e |
| $D_3L_2$ | 39.00 e-g | 29.00 b-e | 9.06 b-d | 8.12 de | 314.44 b-d |
| $D_3L_3$ | 40.33 c-g | 28.33 b-e | 9.03 b-d | 8.63 abc | 315.64 b-d |
| $D_3L_4$ | 38.00 e-g | 26.00 de | 9.00 cd | 8.27 c-e | 298.83 de |
| $D_3L_5$ | 48.33 a-c | 34.33 ab | 9.50 a | 8.12 de | 321.70 b-d |
| $D_3L_6$ | 0.01 h | 0.01 f | 0.0 e1 | 0.01 f | 0.01 f |
| CV(%) | 11.61 | 12.71 | 2.55 | 3.48 | 7.07 |
| P value | 0.063 | 0.089 | 0.069 | 0.002 | 0.008 |
| Level of significance | * | * | * | * | * |

*$D_1$= 6 hrs, $D_2$= 8 hrs, $D_3$= 10 hrs, $L_1$=35 W LED, $L_2$=30 W LED, $L_3$=24 W LED, $L_4$=20 W LED, $L_5$=100 W IB (Incandescent bulb), $L_6$ =no light (control), *= 5 % level of significant*

**Table 3. Continued**

| Treatments | Skin wt. (g) | Skin thickness (cm) | TSS (%) | Yield/ pillar (kg) | Yield/ha (ton) |
|---|---|---|---|---|---|
| $D_1L_1$ | 131.75 cd | 0.26 c-h | 7.80 d-f | 10.29 a-d | 16.47 a-d |
| $D_1L_2$ | 120.50 d | 0.26 d-h | 7.82 d-f | 11.52 ab | 18.43 ab |
| $D_1L_3$ | 156.00 ab | 0.32 a | 10.12 a | 10.20 a-d | 16.33 a-d |
| $D_1L_4$ | 121.60 d | 0.28 c-f | 7.20 ef | 7.40 f | 11.84 f |
| $D_1L_5$ | 135.23 b-d | 0.27 c-g | 8.12 c-e | 12.41 a | 19.85 a |
| $D_1L_6$ | 0.01 e | 0.01 i | 0.01 g | 0.01 g | 0.01 g |
| $D_2L_1$ | 127.00 cd | 0.25 f-g | 7.80 d-e | 9.35 b-f | 14.96 b-f |
| $D_2L_2$ | 136.50 b-d | 0.29 a-c | 7.98 de | 9.87 b-e | 15.80 b-e |
| $D_2L_3$ | 140.25 a-d | 0.23 h | 9.72 ab | 9.00 c-f | 14.40 c-f |
| $D_2L_4$ | 158.50 a | 0.25 d-h | 8.98 bc | 7.46 ef | 11.93 ef |
| $D_2L_5$ | 137.65 a-d | 0.24 gh | 9.71 ab | 10.54 a-c | 16.87 a-c |
| $D_2L_6$ | 0.01 e | 0.01 i | 0.01 g | 0.01 g | 0.01 g |
| $D_3L_1$ | 135.11 b-d | 0.25 e-h | 7.50 d-f | 7.89 d-f | 12.63 d-f |
| $D_3L_2$ | 133.73 cd | 0.28 b-e | 8.22 cd | 9.15 b-f | 14.64 b-f |
| $D_3L_3$ | 145.73 a-c | 0.25 f-g | 6.95 f | 8.87 c-f | 14.20 c-f |
| $D_3L_4$ | 124.75 cd | 0.31 ab | 8.30 cd | 7.66 ef | 12.25 ef |
| $D_3L_5$ | 139.50 a-d | 0.28 bcd | 10.02 a | 11.05 a-c | 17.68 a-c |
| $D_3L_6$ | 0.01 e | 0.01 i | 0.01 g | 0.01 g | 0.01 g |
| CV(%) | 9.23 | 6.99 | 6.68 | 15.53 | 15.53 |
| P value | 0.038 | 9.24E-05 | 1.74E-06 | 0.817 | 0.817 |
| Level of significance | * | * | * | * | * |

*$D_1$= 6 hrs, $D_2$= 8 hrs, $D_3$= 10 hrs, $L_1$=35 W LED, $L_2$=30 W LED, $L_3$=24 W LED, $L_4$=20 W LED, $L_5$=100 W IB (Incandescent bulb), $L_6$ =no light (control), *= 5 % level of significant*

### 3.5 Interaction Effect

Flowering can be induced by increased day length in case of long day plants [28,29]. Significant variation was found among the studied traits due to interaction between light intensity and light duration (Table 3). The response of red flesh dragon fruit to flowering is more than the white fleshed dragon fruit [30]. In case of bud/pillar, treatment $D_1L_5$ produced the maximum number of bud/pillar (54.00) and treatment $D_1L_4$ provided the minimum number of bud/ pillar (34.33). The nutritional status of shoot could be affected by light intensity that influences flowering [19,31]. Flowering occurs in several flushes in dragon fruit in the northern hemisphere between May and October [32]. Treatment $D_1L_5$ also produced the highest number of fruit/ pillar (36.33), maximum fruit length (9.66 cm) and fruit breadth (8.99 cm), yield/ pillar (12.41 kg) and yield (19.85 t/ha). Generally the fruits were larger and sweeter during winter season in Taiwan [2]. Cooler temperatures favor cell division resulting in the formation of larger fruit size [33,34]. In case of fruit weight, the maximum fruit weight (370.70 g) was attained from treatment $D_1L_1$ which is statistically identical with treatment $D_1L_2$ (336.64 g), $D_1L_5$ (339.75 g), $D_2L_2$ (352.56 g), $D_2L_5$ (349.53 g). Treatment $D_2L_4$ produced the highest skin weight (158.50 g) and the minimum skin weight was acquired from $D_1L_2$ (120.50), Treatment $D_3L_5$ provided the maximum TSS (10.02 %) and the minimum TSS was obtained from $D_3L_3$ (6.95 %). Treatment $L_6$ in combination with other light duration did not provided any bud, flower and fruit. It is the clear evidence that, lighting can influence the fruit production during off-season. So treatment $D_1L_5$ can be considered as best production technique for off season dragon fruit production.

## 4. CONCLUSION

Day length is an important factor for fruit production. There is no fruit yield in absent of light (control) during off season because the day length was not optimum for flowering and fruiting of dragon fruit. Considering yield and yield contributing characters, the treatment $D_1L_5$ (6 hrs lighting duration with 100 W IB) can be considered as best technique for off season dragon fruit production under the climatic condition of Bangladesh.

## ACKNOWLEDGEMENTS

We are grateful to Director General (DG), Bangladesh Agricultural Research Institute for his financial support to conduct this experiment. We want to thank the support staff of Agricultural Research Station, Pahartali, Khulshi, Chattogram for their support in different aspects until the experiment was completed successfully.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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